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Assessing the Impact of Eucalyptus Plantation on Groundwater Availability in Pakistan

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Abstract: Eucalyptus tree was first planted in Pakistan in the 1980s under the project of Pakistan Forest Institute sponsored by United States Agency for International Development. It is not native to Pakistan's environment, so it has become a threat to the ecosystem. A mature Eucalyptus tree shape is like a shrub or tall tree. It is centered by the number of controversies like allelopathy, loss of soil fertility, the substitution of conventional forests and causing various hydro-ecological imbalances of an ecosystem. Eucalyptus tree consumes three times more water in arid and semi-arid environments, because of vapor pressure deficit. About 80% of Pakistan's area is present in the semi-arid and arid climate. Pakistan is facing a serious water shortage and rapid groundwater level depletion in many parts of the country. It is believed that species of Eucalyptus tree are extracting more groundwater than water recharge. Therefore, the present study is conducted to identify the adverse impacts of Eucalyptus plantation on the groundwater level of Lahore. Six parks in Lahore were selected as study sites, i.e., Gulshan-e-Iqbal Park, Bagh-e-Jinnah, Jillani Park, Nawaz Sharif Park, Jallo Park, and Johar Town Park. A total of 3,484 Eucalyptus trees were identified with different age groups. These trees belong to the species of *Eucalyptus camaldulensis*, *Eucalyptus citriodora* and *Eucalyptus sideroxylone*. The study reveals that since 1990, the groundwater level has significantly reduced in study sites. It is recommended that Eucalyptus trees may be replaced with other indigenous species so that the rate of groundwater depletion can be slowed down.

Keywords: Eucalyptus, GPS, groundwater, water depletion, Lahore.

Introduction

Good quality drinkable water is essential for human health and survival. Both groundwater and surface water are significant sources for public water supply. However, groundwater is commonly used for drinking purpose in many parts of the world. It is also an essential source of water supply for industrial and agricultural activities. The demand for water has increased over the years due to increase in population, and this has led to water scarcity throughout the world. Groundwater level depletion is inevitable and natural consequence of withdrawing water from an aquifer (Konikow and Kendy, 2005). Groundwater is used for drinking purpose by at least 50% of the global population and accounts for 43% of all of the water used for irrigation. Worldwide, 2.5 billion people depend solely on groundwater resources to satisfy their basic daily water needs (WWDR, 2015). About 8.2% of inexhaustible groundwater is annually withdrawn for human use (Kanwal et al., 2015). Without maintaining groundwater reserves, global water safety is at far higher risk than is presently recognized. Change in climate and related changes to the water cycle immensely complicate the challenge of assisting groundwater supplies for the future (Famiglietti, 2014). Groundwater is the primary source of drinking water in both urban and rural areas of Pakistan. It is roughly calculated that about 60-70% of inhabitants of Pakistan directly or indirectly depend on groundwater for their livelihood. In rural areas, about 80% of the domestic water supply is met by groundwater.

Eucalyptus tree is a large genus of family Myrtaceae, with more than 700 species; most of them are native to Australia (Abbas et al., 2010). As a fast-growing, well paid, and frequently demanded industrial wood, it is among extensively planted tree species, covering almost 20 million ha all over the world (Srivastava et al., 2003; Hubbard et al., 2010). It is centered by several controversies like allelopathy, loss of soil fertility, adverse effects on local food security, the substitution of conventional forests and causing various hydro-ecological imbalances of an ecosystem (Chu et al., 2014; Palmberg, 2002; Zegeye, 2010; Dessie and Erkossa, 2011). The main adverse effect of the Eucalyptus tree is that it is high water-consuming species. It can consume 50 to 90 liters of water per day per plant in the fair supply of water (Joshi and Palanisami, 2011). A three-year Eucalyptus tree can consume 100 liters of water in a 24-hours cycle (NIAB, 1990). In dry season or shortage of water, its roots can reach up to 20-30 feet depth. Some Eucalyptus tree species reach maximum rooting depths of about 60 meters in deep soil layers to the water table, and depletes groundwater resources (Stone and Kalisz, 1991; Laclau et al., 2001b; Bilal et al., 2014; Christina et al., 2017; Bayle, 2019). Their high-water requirement and deep root system can be particularly damaging in terms of water usage, if Eucalyptus trees are planted in arid regions (Palmberg, 2002). The issue of water use by this tree species is causing debate in many regions, including Southeast Asia (White et al., 2016). In Pakistan, groundwater is used for domestic as well as irrigation purposes. Hence, the groundwater level is dropping about 3 feet per year. In Lahore, due

to huge increase in population and urbanization, the use of groundwater has drastically increased. Now the consumption of groundwater is far more than its recharge. This is causing rapid depletion in the groundwater level. In the central part of the Lahore city, the groundwater level has fallen below 130 feet, and in 2025 it will drop below 230 feet. The groundwater level declining rate in the district Lahore is 2.5 to 3.0 feet per year. This situation can worsen further in the year 2040, if the present condition persists (Kanwal et al., 2015; WWF, 2017).

In 1980s United States Agency for International Development (USAID) funded a forestry planting and development project in Pakistan, and Eucalyptus tree was selected for this purpose because it survives in adverse conditions. It is a non-native species in Pakistan; therefore, it is creating a threat to the ecosystems and humans (Huang and Asner, 2009). Recently, Pakistan is facing a severe shortage of water for agricultural, drinking and industrial uses. Furthermore, the natural groundwater recharge is already very slow. Therefore, there is an immense need to study and analyze the factors that are causing groundwater depletion. Eucalyptus tree species are consuming more water and lowering groundwater level (Zahid and Ahmad, 2002). In a study conducted by Bilal et al. (2014) in district Malakand, it was proved that the Eucalyptus trees have an adverse effect on both surface and groundwater. It has lowered the water table by 0.762 m per year and also many springs dried out after Eucalyptus tree plantation in that area. The present study aims to identify Eucalyptus trees and to find out the impact of Eucalyptus plantation on the groundwater level depletion in Lahore.

Materials and Methods

Study Area

Lahore is the provincial capital of Punjab and the second-largest metropolis of Pakistan. According to the census of 2017 the population of Lahore city is 11,126,285 people (PBS, 2017). Its area is about 1,772 square kilometers. It is located between 74° 20′ 37″ E and 31° 32' 59″ N latitude and longitude, respectively (Kanwal et al., 2015). The hottest months of the year are June and July with 40°C to 48°C temperature range, while December and January are coldest months. There is a monsoon season from June to August but January and February also receive rainfall (Siddiqui et al., 2016). Lahore city is drained by the Ravi river which enters Pakistan near a village Auliapur (Sheikhupura). Due to the withdrawal of water from this river, the recharge of Lahore aquifers gradually started declining. An increase in population, expanding industry, higher demand for gardening, recreation and increased pumping of water caused groundwater level depletion. In Punjab rainfall affects the groundwater level only when it exceeds 10 to 14 inches in a year (Abbasi, 1977). The study sites comprise some major parks of Lahore, including Jillani Park (Race Course Park), Johar Town park, Bagh-e-Jinnah (Jinnah Garden), Gulshan-e-Iqbal park, Jallo park and Nawaz Sharif park (Fig. 1).

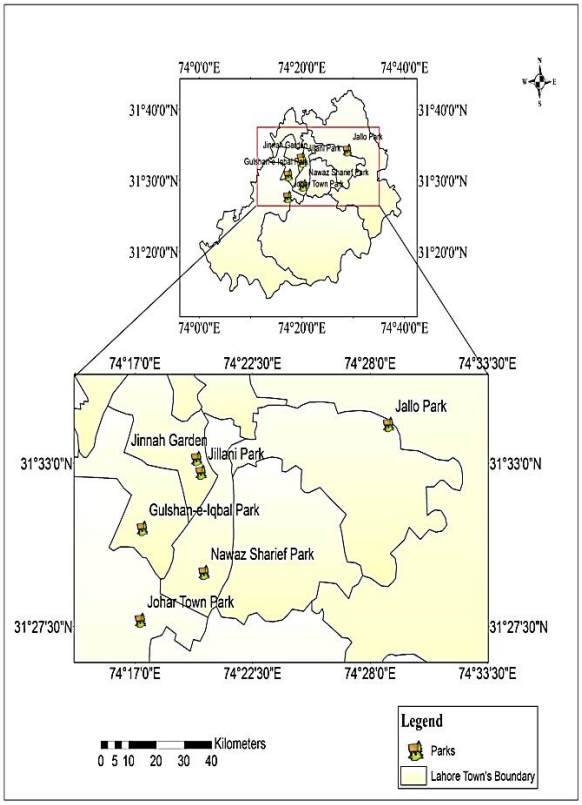

Fig. 1 Location of selected study sites (parks) in Lahore.

A number of Eucalyptus trees, their species, distribution, and age estimation were performed during a field survey in the parks. Individual tree locations were noted by using the Global Positioning System (GPS), and Girth of the tree was measured with measuring tape, to calculate the tree age. Girth is measured one meter vertically above from the base of tree. The average growth rate of Girth for trees is 2.5 cm. Age calculated from Girth by using a formula, which is Girth (cm) ÷ 2.5 cm. Daily and annual average water consumption by identified Eucalyptus trees were estimated. Linear regression analysis was done and the trend line was set for groundwater level depletion in each study site. The groundwater level data of the last 27 years (1991 to 2017) were acquired from WASA (Water and Sanitation Authority) Pakistan and Punjab Forest Department. The data were taken from the bore wells depth, which were located near or within the study area.

Results and Discussion

Distribution of Eucalyptus Tree Species

In the study area, a total of 3,526 Eucalyptus trees were identified and analyzed. A higher number of *Camaldulensis* species is found in all parks, while other species are *Citriodora* and *Sideroxylone.* Jallo park has the highest number of (2,975) Eucalyptus

Fig. 2 Eucalyptus tree species found in the study area.

trees which were planted to cope with the groundwater salinity. *Citridora* is also found in all parks except Gulshan-e-Iqbal and Jillani parks. In Jallo park *Camaldulensis*, *Citridora* and *Sideroxylone* species were also found while *Sideroxylone* is planted in Jallo park (Figs. 2; Table 1).

Table 1 Number of Eucalyptus tree species in selected parks.

Study Sites	**Eucalyptus Tree Species**			**Total Trees**
	Camaldule-nsis	***Citrid-ora***	***Sideroxyl-one***	
Gulshan-e-Iqbal Park	208	-	-	208
Jillani Park	40	-	-	40
Johar Town Park	96	76	-	172
Nawaz Sharif Park	60	29	-	89
Jallo Park	1,200	275	1,500	2,975
Bagh-e-Jinnah	42	-	-	42
Total	1,646	380	1,500	3,526

Groundwater Level in Study Sites

Average annual groundwater level data acquired from WASA (2017) for the past 28 years indicate that in all study sites groundwater level has gradually declined (Figs. 3a, b, c, d, e, f). Groundwater level depletion is mainly caused by sustained groundwater pumping to meet the demand of overgrowing population. However, the high demand for water by Eucalyptus plantation cannot be neglected in arid regions like Lahore and Pakistan. Furthermore, the groundwater recharge also tends to decrease with the increasing number of Eucalyptus plantations and low precipitation.

Estimation of Eucalyptus Tree Water Consumption

Water consumption of a tree depends upon many factors like humidity, temperature, evapotranspiration, size of a tree and adequacy of water. Joshi and Palanisami (2011) reported that young Eucalyptus tree's average water uptake is 50 liter/d/plant to 90 liters/d/plant. According to Rodríguez-Suárez et al. (2011), in the first three years of Eucalyptus growth, groundwater depletion level remains constant, and then it is increased year by year, and after seven years this rate is stabilized (White et al. 2016; Rodríguez-Suárez et al. (2011; Joshi and Palanisami, 2011). Present study estimated direct consumption of groundwater by 3,526

identified Eucalyptus trees, using previously reported age-wise water consumption in liters per day (Table 2).

Table 2 Consumption of Groundwater by Eucalyptus Trees in Study area: GIP: Gulshan-e-Iqbal park, BAJ: Bagh-e-Jinnah, JIP: Jillani park, JTP: Johar Town park, NSP: Nawaz Sharif park, JAP: Jallo park.

Study Sites	Total Trees	Average Age of rees in Years	Daily Average Water Consumption by One Tree in Liters (L)	Daily Average Water Consumption by Total Trees in Liters (L) Total Trees x One ay Water Consumption (L)	Average Annual Water Consumption by Total Trees in Liters (L) One Day Water consumption by Total Trees x 365
GIP	208	30	55	208 x 55=**11,440**	11,440 x 365=**4,175,600**
BAJ	42	40	70	42 x 70=**2,910**	2,910 x 365=**1,073,100**
JIP	40	25	50	40 x 70 =**2,000**	2,000 x 365 =**730,000**
JTP	172	35	60	172 x 60 =**10,320**	10,320 X 365=**3,766,800**
NSP	89	25	50	89 x 50=**4,450**	4,450 x 365=**1,624,250**
JAP	2,975	30	55	2,975 x 55= **163,625**	163,625 x 365= **59,723,125**

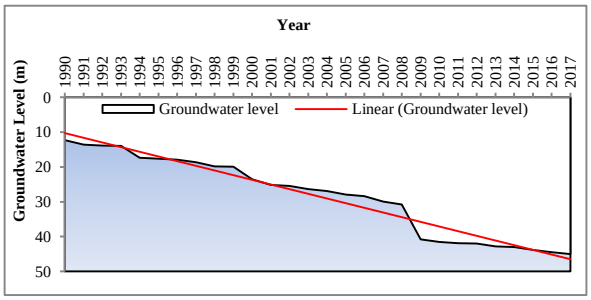

Fig. 3a Average annual groundwater level (meters) in Gulshan-e-Iqbal Park.

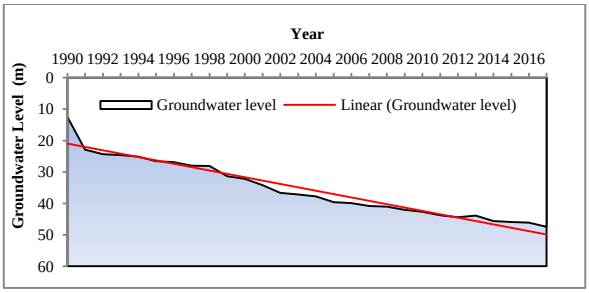

Fig. 3b Average Annual Depletion of Groundwater Level (meters) in Jillani Park.

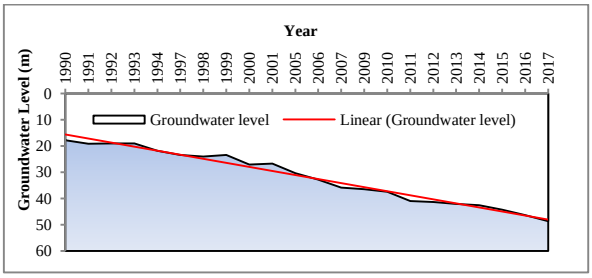

Fig. 3c Average annual groundwater level (meters) in Nawaz Sharif Park.

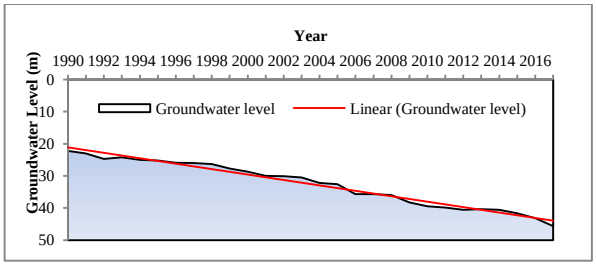

Fig. 3d Average annual groundwater level (meters) in Bagh-e-Jinnah.

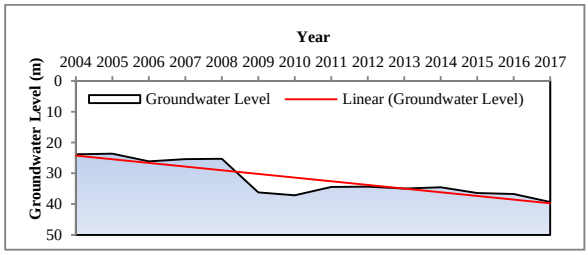

Fig. 3e Average annual groundwater level (meters) in Johar Town park.

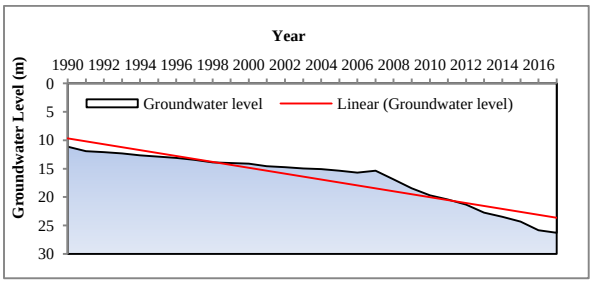

Fig. 3f Average annual groundwater level (meters) in Jallo park.

Conclusion

Eucalyptus is a controversial species in almost all over the world, especially in arid and semi-arid regions. Its evapotranspiration rate is higher than other native species, which indicate that it is not a suitable species for those areas which are facing an acute shortage of water. Due to recent dreadful water shortage and rapid groundwater level depletion in Pakistan, it is believed that Eucalyptus species are extracting more groundwater than water recharge thus depleting groundwater level. From the areas facing severe groundwater shortage, the Eucalyptus trees has to be phased out gradually. Eucalyptus is consuming 12% groundwater of the country. An estimated number of hundreds of thousands of Eucalyptus species are in Lahore. However, the exact number for Eucalyptus trees in Lahore is not known. Therefore, a complete inventory of Eucalyptus trees in Lahore should be prepared for gradually removing Eucalyptus trees. Moreover, the groundwater and surface water resources should be monitored regularly to determine the water table level in these areas by keeping in view the possible adverse effects of these species on the environment. Furthermore, it is not possible to ban Eucalyptus trees in Pakistan because of large saline and waterlogged area in some parts of the country. Therefore, Eucalyptus should be planted only in the waterlogged areas. It is essential to aware farmers and the public, not to grow these trees in the fields, homes, or the public parks. The places where these trees exist, like public parks, roadsides, and/or houses, it should be replaced with native plant species. The new trees will grow over a three to five years period and take the place of the Eucalyptus trees. People will face a substantial massive water crisis in the next few years so, it's a need of time to conserve or save water in every possible way. The government must take the necessary action by cutting or uprooting the Eucalyptus trees, by replacing them with other indigenous trees or plants of similar Girth, such as the *Neem, Arjun, Peepul, Amaltas, Keekar, Burma, Sukchain*.

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